

(19)

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(11)

EP 1 362 986 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:  
19.11.2003 Bulletin 2003/47

(51) Int Cl.7: F01L 1/344, F01L 1/047

(21) Application number: 02253494.5

(22) Date of filing: 17.05.2002

(84) Designated Contracting States:  
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE TR  
Designated Extension States:  
AL LT LV MK RO SI

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(54) Variable camshaft assembly

(57) A variable camshaft assembly has a first cams 18a, 18b that can be moved relative to a second cam 16. The assembly comprising a tube 14 fast in rotation with the first cam 18 and rotatably supporting the second cam 16 and a drive shaft 12 disposed within the tube 14

and coupled for rotation with the second cam 16 by means of a connecting pin 20 that passes with clearance through a hole 24 in the tube 14. The connecting pin is a hollow pin 20 that is a sliding fit in the second cam 16 and that is expanded in situ to form an interference with the drive shaft 12.

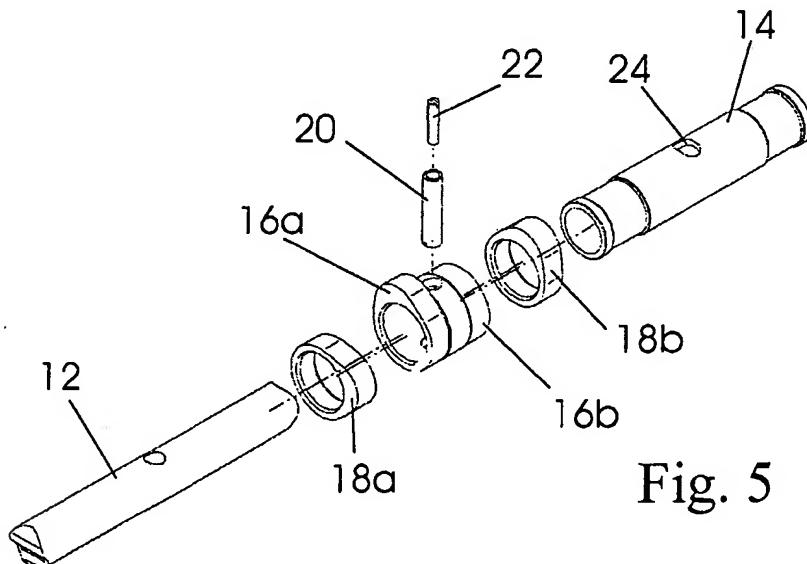


Fig. 5

**Description****Field of the invention**

[0001] This invention relates to a variable camshaft assembly in which one set of cam lobes can be moved relative to a second set of cam lobes.

**Background of the invention**

[0002] Camshaft assemblies are known which comprise a tube to which some of the cam lobes are fixed and about which other cam lobes are free to rotate. A drive shaft that passes through the bore of the tube and connecting pins that pass with clearance through an aperture in the tube couple the rotatable cam lobes to the drive shaft. The angle of the individual cam lobes can thus be controlled by setting the angle of the drive shaft relative to the drive tube.

[0003] In order to minimise any angular variation between the cam lobes attached to the drive shaft, it is advantageous to retain the connecting pins in the shaft via an interference fit, whilst the connecting pins have a small clearance in the cam lobes. If the clearance fit were to be located at the interface between the pins and the drive shaft, a more significant angular variation would result.

[0004] It should be noted that the connecting pins cannot be an interference fit in both the drive shaft and the cam lobe as small tolerance variations would result in the assembly becoming locked. The cam lobe axis of rotation is defined by the sliding fit on the outer surface of the tube and the drive shaft is required only to give angular alignment of the cam lobe. If there were to be no clearance in the system, the drive shaft would also attempt to determine the cam lobe axis of rotation and hence small tolerance variations would prevent the assembly from rotating freely.

[0005] In order to allow the assembly of the connecting pins into the drive shaft, it is necessary to ensure that the axial force applied to the pin to overcome the interference fit in the drive shaft cannot cause the shaft to bend beyond its elastic limit. This has been achieved in the past by providing bearing areas on the drive shaft that are a running fit in the bore of the tube adjacent to each of the connecting pins. The assembly can then be supported on the cam lobe or the tube whilst the connecting pins are pressed into position without the drive shaft becoming distorted.

[0006] Whilst this design has been demonstrated to be a successful method of producing a camshaft assembly of this type, it does have two disadvantages, namely:

- The whole bore of the tube must be accurately positioned to its outer diameter and finished to an accurate diametral tolerance.
- A number of bearing areas need to be finished on the shaft to an accurate tolerance and these are

subsequently redundant once the components have been assembled since only two bearings are necessary to position the shaft in the bore of the tube.

[0007] These two factors can have a significant effect upon the ease of manufacture and hence the cost of the assembly and the aim of the invention is to mitigate these problems.

[0008] In accordance with a first aspect of the invention, there is provided a method of assembling a variable camshaft assembly having a first cam lobe that can be moved relative to a second cam lobe, the assembly comprising a tube to which the first cam lobe is fixed and about which the second cam lobe is free to rotate, a drive shaft that passes through the bore of the tube and a connecting pin that passes with clearance through an aperture in the tube to couple the second cam lobe for rotation with the drive shaft, which method comprises inserting into holes in the cam lobe and in the drive shaft a hollow connecting pin having a constant outer diameter dimensioned to be a close fit in the holes, and expanding the outer diameter of the connecting pin only within the region of the pin that lies within the drive shaft so that an interference fit is generated with the drive shaft.

[0009] Preferably, the connecting pin has an inner diameter that varies along its length, being larger at its end engaging the cam lobe than at its region in line with the drive shaft, and the outer diameter of the pin is expanded by inserting into the pin an element of larger outer diameter than the smaller inner diameter region of the connecting pin.

[0010] The element used to expand the pin may be a pin, a ball or a screw that remains within the pin after assembly is completed. Alternatively, it may be a mandrel that is withdrawn from the pin after it has locally stretched the pin beyond its elastic limit.

[0011] In accordance with a second aspect of the invention, there is provided a variable camshaft assembly having a first cam that can be moved relative to a second cam, the assembly comprising a tube fast in rotation with the first cam and rotatably supporting the second cam and a drive shaft disposed within the tube and coupled for rotation with the second cam by means of a connecting pin that passes with clearance through a hole in the tube, wherein the connecting pin is a hollow pin that is a sliding fit in the second cam and that is expanded in situ to form an interference with the drive shaft.

[0012] Because the pin can be expanded into an interference fit with the drive shaft without applying an excessive force tending to bend the drive shaft, it is no longer necessary for the drive shaft to be supported along its entire length and it can instead, in accordance with a preferred feature of the invention, be journalled in the surrounding outer tube at only two locations, pref-

erably its axial ends, leaving a clearance between the drive shaft and the tube over the major proportion of its length. Such a clearance obviates the need for the entire bore of the tube and the outer surface of the drive shaft to be accurately machined.

[0013] The bearings may each take the form of an inserted bush, or the drive shaft could run directly against a machined surface inside the tube.

#### Brief description of the drawings

[0014] The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a side view of a camshaft of a first embodiment of the invention,  
 Figure 2 is a section along the section line A-A in Figure 1,  
 Figure 3 is a section along the section line B-B in Figure 1,  
 Figure 4 is a perspective view of the camshaft of Figure 1 in its assembled state,  
 Figure 5 is an exploded perspective view of the camshaft shown in Figures 1 to 4,  
 Figure 6 is a section similar to that of Figure 2 showing a second embodiment of the invention,  
 Figure 7 is a section similar to that of Figure 3 showing the second embodiment of the invention,  
 Figure 8 is a section similar to that of Figure 3 showing a third embodiment of the invention, and  
 Figure 9 is a section similar to that of Figure 2 illustrating a fourth embodiment of the invention.

#### Detailed description of the preferred embodiments

[0015] In all the figures, a camshaft 10 is shown that comprises an inner drive shaft 12 journaled within an outer tube 14. Cams 18a and 18b are directly mounted on the tube 14 for rotation therewith and further cams 16a and 16b are freely rotatable about the tube 14 and are connected for rotation with the drive shaft 12 by means of a hollow pin 20 that passes with clearance through a hole 24 in the outer tube 14. This construction is common to all the described embodiments which only differ from one another in the manner in which the pin 20 is made to engage in the drive shaft 12.

[0016] In the first embodiment shown in Figures 1 to 5, the bore of the connecting pin 20 is formed with two different diameters, the central portion having a diameter that is smaller than that of the two ends. A cylindrical element 22 is inserted into the pin 20 after it has been inserted into the drive shaft 12. The element 22 is an interference fit in the central portion of the connecting pin 20 and its insertion causes the outer diameter of the pin 20 to expand also, thus retaining the pin 20 in the drive shaft 12. If the cylindrical element were to be removed, the pin would return to its original size and could

be removed simply.

[0017] In the case of the second embodiment, shown in Figures 6 and 7, a tapered thread or an interference fit thread is provided on an element 122 that can be screwed into the bore of the connecting pin to fix the pin in position in the drive shaft. A slot or similar feature is required in one end of the connecting pin 20 to prevent the pin from rotating as the threaded element 122 is screwed into position.

[0018] The third embodiment of Figure 8, is similar in concept to the first embodiment, but one or more spherical elements 222 are pushed into the bore of the connecting pin 20 in order to expand it into the bore in the drive shaft 12.

[0019] A fourth embodiment of the invention, shown in Figure 9, avoids the need to insert an additional component into the bore of the connecting pin 20. Instead, the connecting pin has a mandrel 322 forced through it which is sized such that the central portion of the connecting pin 20 is expanded considerably beyond its elastic limit, and therefore remains an interference fit in the drive shaft 12, even when the mandrel 322 has been removed.

[0020] In all the embodiments of the invention, the force applied to the connecting pin by the insertion of the locking elements or mandrel can be resisted on the end of the connecting pin itself and there will be no tendency to bend the drive shaft. For this reason, it suffices to support the drive shaft 12 within the outer tube at only two axially spaced bearing locations, which may be formed either by suitably machined surfaces or an inserted bush. The need to machine the inner diameter of tube 14 and the outer diameter of the drive shaft 12 accurately over their entire length is thus obviated.

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#### Claims

1. A method of assembling a variable camshaft assembly having a first cam lobe (18) that can be moved relative to a second cam lobe (16), the assembly comprising a tube (14) to which the first cam lobe (18) is fixed and about which the second cam lobe (16) is free to rotate, a drive shaft (12) that passes through the bore of the tube (14) and a connecting pin (20) that passes with clearance through an aperture (24) in the tube (14) to couple the second cam lobe (16) for rotation with the drive shaft (12), which method comprises inserting into holes in the second cam lobe and in the drive shaft a hollow connecting pin (20) having a constant outer diameter dimensioned to be a close fit in the holes, and expanding the outer diameter of the connecting pin (20) only within the region of the pin that lies within the drive shaft (12) so that an interference fit is generated with the drive shaft (12).
2. A method as claimed in claim 1, wherein the con-

necting pin (20) has an inner diameter that varies along its length, being larger at its end engaging the cam lobe than at its region in line with the drive shaft, and the outer diameter of the pin is expanded by inserting into the pin an element (22) of larger outer diameter than the smaller inner diameter region of the connecting pin.

3. A method as claimed in claim 2, wherein the inserted element (22) is cylindrical. 10
4. A method as claimed in claim 2, wherein the inserted element (222) is spherical.
5. A method as claimed in claim 2, wherein the inserted element (122) is a screw. 15
6. A method as claimed in claim 2, wherein the inserted element is a mandrel that is withdrawn from the pin after it has locally stretched the pin beyond its elastic limit. 20
7. A variable camshaft assembly having a first cam (18) that can be moved relative to a second cam (16), the assembly comprising a tube (14) fast in rotation with the first cam (18) and rotatably supporting the second cam (16) and a drive shaft (12) disposed within the tube (14) and coupled for rotation with the second cam (16) by means of a connecting pin (20) that passes with clearance through a hole (24) in the tube (14), wherein the connecting pin (20) is a hollow pin that is a sliding fit in the second cam (16) and that is expanded in situ to form an interference with the drive shaft (12). 25
8. A variable camshaft as claimed in claim 7, wherein the drive shaft (12) is rotatably supported within the tube (14) at only two bearing locations and is spaced from the tube along the remainder of its length. 30
9. A variable camshaft as claimed in claim 8, wherein the bearing locations include bushes arranged between the drive shaft and the surrounding tube. 35
10. A variable camshaft as claimed in claim 8, wherein the drive shaft and the surrounding tube are machined to make direct contact with one another at the bearing locations. 40

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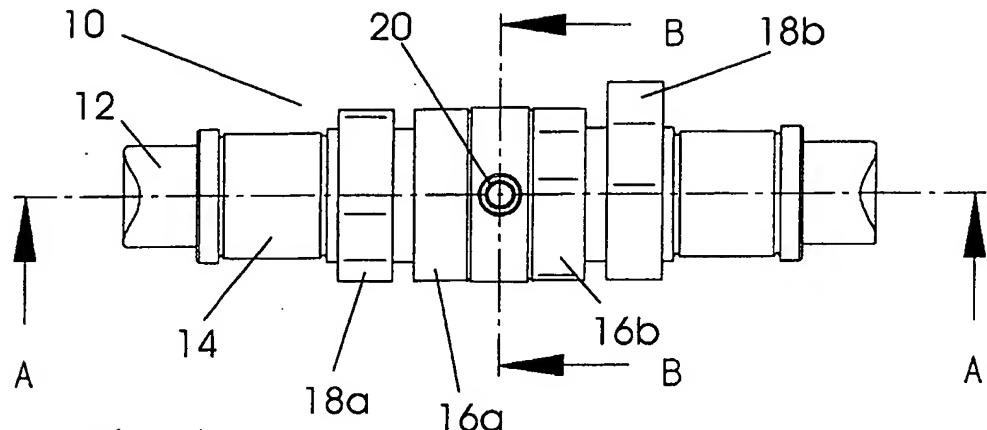


Fig. 1

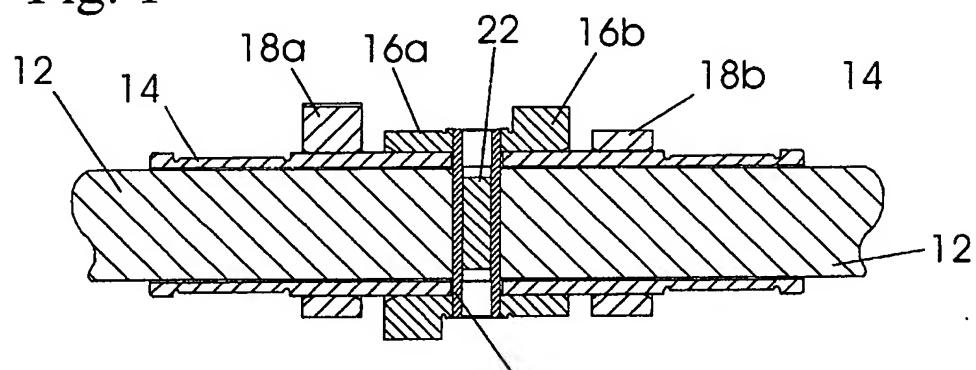


Fig. 2

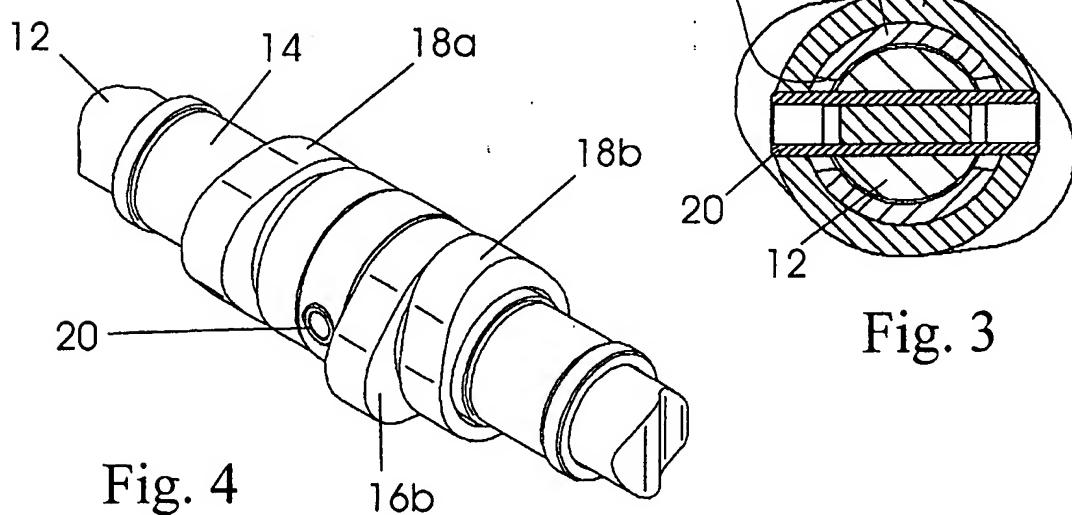


Fig. 4

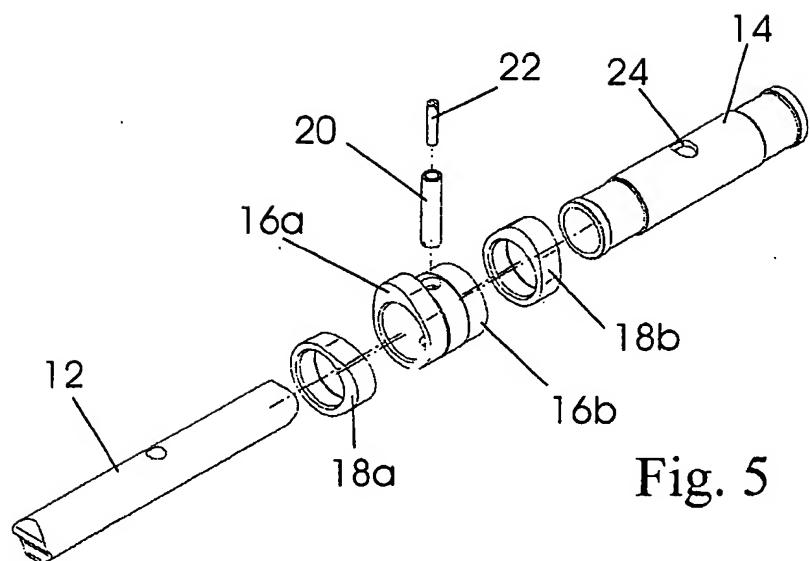


Fig. 5

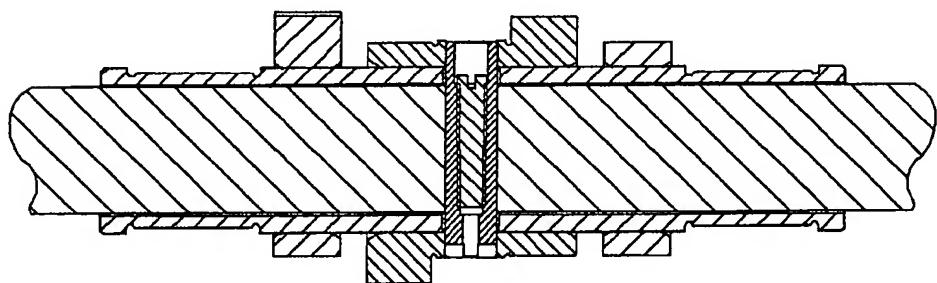


Fig. 6

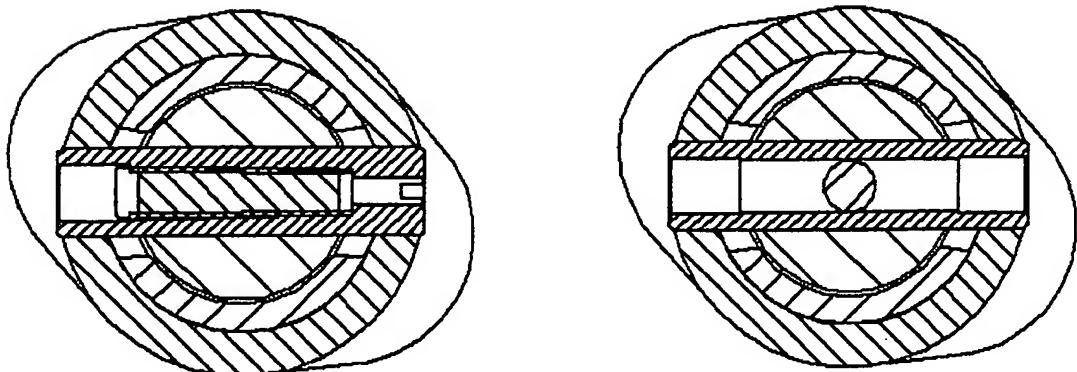


Fig. 7

Fig. 8

DIRECTION  
OF MANDREL  
MOTION

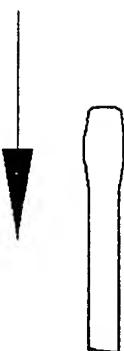
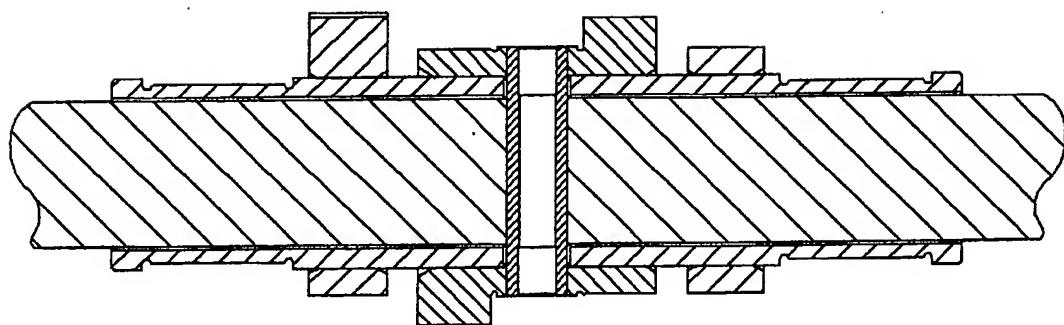


Fig. 9





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## EUROPEAN SEARCH REPORT

Application Number  
EP 02 25 3494

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim							
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)						
			F01L F16H						
<p>The present search report has been drawn up for all claims</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%;">Place of search</td> <td style="width: 33%;">Date of completion of the search</td> <td style="width: 34%;">Examiner</td> </tr> <tr> <td>THE HAGUE</td> <td>26 August 2002</td> <td>Klinger, T</td> </tr> </table>				Place of search	Date of completion of the search	Examiner	THE HAGUE	26 August 2002	Klinger, T
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THE HAGUE	26 August 2002	Klinger, T							
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document							
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document									

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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EP 02 25 3494

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EOP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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